

Contribution of NOAA- AVHRR data to African savannahs Characterization.

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Abstract : The Advanced Very High Resolution Radiometer (AVHRR) is currently used for vegetation monitoring. Information on the state and evolution of the vegetation cover on continental areas is routinely obtained from Global Vegetation Index data (GVI). In this paper some aspects of continental level, biome features were interpreted from a global scale GVI time series acquired with the NOAA/AVHRR between 1986 and 1990. A biome classification scheme for Africa is proposed. NOAA/AVHRR data were submitted to a cloud filtering algorithm, subsequently calibrated and corrected for atmospheric perturbations. Typical behaviour of Normalised Difference Vegetation Index (NDVI) temporal evolution derived from the AVHRR are classified, colour coded, and mapped to be compared with classical biome cartographic information. Analysis of the temporal GVI shows, that the spatial organisation of natural biomes in Africa changes within a single growing season. Transition zones between major ecological zones can clearly be identified. Furthermore, closer examination of GVI temporal variations, reveals year to year differences assumed to be the result of changes in landscape structure. Results illustrate that this approach is appropriate to describe vegetation temporal dynamics. The approach shows potential to describe climatic and human interactions with African biomes. In this paper results are presented and limitations will be discussed.

Keywords : Classification, African biomes, NDVI, temporal behaviour, AVHRR

1. Introduction

The international scientific community has developed several coordinated actions tackling issues like climate change, land degradation, and more generally, actions to enhance our understanding of the activity of the terrestrial biosphere on a global scale. Data gathered in view of Global Change research are closely related to the evolution of the biosphere and more particularly with terrestrial vegetation. Some of these activities have been defined by the IGBP and GCTE programmes and were described by NRC [1] IGBP [2]. The state of terrestrial vegetation is directly influenced by climatic events as well as by anthropogenic activities [3]. Reciprocally and by feed-back mechanisms, the Earth's biosphere influences climate through its control of the carbon, water and nutrient cycles and energy exchange, interactions. Data of only a few operational satellite based sensors are actually available to characterise the state of the biosphere on a global scale through classification [4]. The AVHRR sensor aboard the satellites of the NOAA series has been widely used in the scientific community because of its spectral bands in the visible (0.58-0.68 μm) and near-infrared (0.72-1.1 μm). NOAA data allow for the monitoring of vast territories with an accurate temporal repetitiveness [5]. Our objective is focused on the

development of classification strategies to open perspectives in our understanding of terrestrial biome behaviour. The first part of this publication aims at characterising the temporal and spatial behaviour of Western African biomes on a continental scale. This approach is based on a automatic classification, unsupervised, without any other information than a filtering and smoothing NOAA-AVHRR data set. Our study is based to analysis what the output means in term of delimitation and characterization of African biomes. Of these biomes, the various savanna types represent a transition between humid evergreen forest and tropical and sub-tropical dry regions. Submitted to climatic and anthropogenic effects, this biome gradually evolves, in terms of cover heterogeneity and relative abundance of various arboreous, shrubby and herbaceous strata. These elements account for the difficulties encountered to delimit in absolute terms and hence, to monitor it spatially and temporally. We rely on the data collected within the scope of the SALT regional programme (Savanna on the Long Term [6] of which the main goal is a better understanding of the functioning of the African savanna as well as its interactions with man and climate on a larger temporal scale. In the second part of this article, we will describe in more detail, the analysis of

spatial variability of different savanna types and the multi-annual behaviour of this biome on a regional scale. In this study, data collected in the field allows us to validate classification results obtained at a regional scale. They will also document the appropriateness of NOAA imagery for classification purposes. To that end, we have confronted classification results with data collected from previous maps [7]. For biomes corresponding with the continental and regional scales, data collected from remote sensing imagery were compared with classical cartographic data. This comparison documents the limitations of the proposed approach, and enables us to update our knowledge, and to define more precisely some elements of nomenclature. Indeed, through its capacity to monitor phenological cycles, the remote sensing approach enables us to identify climatic and anthropogenic events whether in the recent past or actual, as far as the observation period is concerned. Hence our classification procedure should contribute to a better understanding of the evolution of terrestrial biomes by an analysis of the phenological evolution of the green cover.

2. Context and objectives

The bio-geography of African ecosystems was initiated by Engler [8]. This first work, mainly consisted of distinguishing between large natural biome subdivisions. Subsequently, nomenclature was detailed further by Chevalier [9], who succeeded in defining the bio-geographical zones of Western Africa, and later, of the entire African continent. His work remains a classical reference because its latitudinal delimitation gives us a first appraisal of the localisation of ecological zones. Lebrun [10] provided with a more precise cartographic description of the big contrasts between dry and wet tropical Africa. More specifically phyto-geographical divisions in Africa and Malagasy were outlined by Monod [11]. The improvement of mapping accuracy came with a better description of the biome attributes for each zone listed. The scientific community had to wait another 10 years, before the first African phyto-geographical maps were developed, taking into account the rain distribution and the dry season duration [12]. Several researchers used this map to define the biogeographical boundaries for several biomes of the African continent. In 1976, Schnell [13] provided with a phyto-geographical synthesis of African flora based on botanical studies. In 1983, UNESCO [14] began to unify bio-geographical maps of different African states. This compilation, accompanied with some considerations on the physical environment, allowed for a map development, which happens to

be the best current synthesis of ecosystem distribution for the African continent. None recently, synthetic studies, were undertaken at the continental scale [15]. They made use of remote sensing observations on the evolution of the environment. Local scale studies provided us with essential information concerning the description of environments as well as a definition of biome types. Nonetheless, the extrapolation of this approach to the regional scale, posed serious methodological problems and does not account for the temporal dynamics of ecosystems. Our study aims at characterising and classifying observed environments by using information inherent to the temporal evolution of the global vegetation index (GVI). Hence, we described phenological behaviour during several vegetation cycles and retrieved information on inter-annual GVI variations, allowing for a description of vegetation dynamics. Our approach largely relies on the main new features elicited by remote sensing information, e.g.; repetitiveness, accessibility and spatial coverage. We centered our research on the characterisation of the behaviour of main biomes in a temporal perspective. It also appeared to us most appropriate, to confront the results issued from this approach with more classical ones related to the description of environments already published.

3. Materials and methods

We used three sources of information, two of which originate from remote sensing, respectively from the sensors NOAA/AVHRR and SPOT/HRV. The last one corresponds with field based cartographic observations. At our disposition, we had, weekly synthesis of NOAA/AVHRR data in the GVI data format with a spatial resolution of 15 kilometres subsampled from an original spectral resolution of 4 kilometre (GAC format [16]). Raster data is in Plate-Carrée projection, hence layered information can be superimposed one on the other. Furthermore the GVI is assumed to be less perturbed by clouds or directional effects of observation [17]. Five uninterrupted years of GVI data were acquired between January 1st 1986 and December 31st 1990 by the NOAA9 and NOAA11 satellites. Because of the orbital drift of the NOAA9 satellite the year 1988 was omitted for too high further use angles. It was therefore decided to use only the years 1986, 1987, 1989 and 1990 for classification purposes. The most important objective of this study is to take into account a long period of observation to minimize the

influence of the local climatic variations on the classification. Due to the extend of the observation period, we can reliably vegetative cover dynamics for several phenological cycles. The information thus obtained is most helpful to define the biomes types and to identify the structural / functional attributes of the biomes observed. As a result we can document the temporal evolution of biomes on an intra- and inter-annual basis. Moreover, relationships can be established between low resolution data such as GVI data and cartographic information based on field observations. This 'ground truth' is spatialised on the SALT site (30 km x 30 km) scale and corresponds with the cartography of natural environments. Use was made of maps representing the state of the surface on the sites corresponding with the central transect. Because of differences in origin and nomenclature, these maps have been interpreted with much caution, nevertheless they allowed us to extract thematic information enabling the characterisation of African biomes.

3.1 Radiometric and atmospheric corrections

Since remote sensing observations have been acquired by different sensors under different conditions in the four years mentioned earlier, we had to make them consistent and inter comparable. A first step consists in standardising apparent reflectances on top of the atmosphere (figure 1).

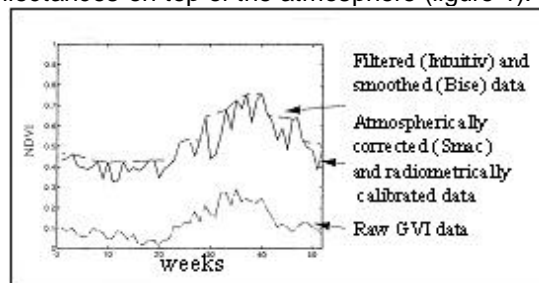


Figure 1: Influence of calibration, atmospheric corrections, filtering and smoothing on raw GVI data. The temporal profile show originates from a GVI pixel, 12°N, 4°W from the Bondoukou region (Burkina Faso).

Calibration was performed with pre-launch calibration coefficients. Since ageing of the sensor involves a drift of its calibration coefficients were used [18] with the scheme for NOAA interpolated calibration coefficients obtained by observations over optically stable sites. This allowed us to calibrate all remote sensing data sets used in this study. NOAA data are also affected by atmospheric radiative transfer perturbations such as diffusion, absorption and reflection of photons during their double crossing of the atmosphere [19]. To minimize these perturbations, we corrected NOAA

and SPOT top atmosphere observations with the SMAC model [20]. SMAC is based on the 5S atmospheric radiative transfer code [21]. SMAC is particularly well adapted for the processing of large temporal series of remote sensing observations. Parametric functions allow for a description of the absorption and diffusion by atmospheric gases and diffusion and reflection by aerosols. Calibration coefficients have been computed for each AVHRR bands (VIS and NIR). Since measurements for the three input parameters of the model (ozone, water vapour and aerosol loading) are lacking, especially for the time period considered and for the number of sites considered in Western Africa, we made use of weekly interpolated climatic data and a spatial resolution of 15 km² for water vapour [22] and ozone [23]. As for the aerosol load of the atmosphere, no information is currently available on this temporal and spatial scale. The spatial and temporal variability of this last atmospheric constituent is quite substantial and does not allow extrapolations based on locally observed values. Hence, we have selected an average value of 0.2 at 550 µm to correct the GVI data set. Temporal series of GVI observations are still affected by atmospheric perturbations. Some of these effects have been documented by Holben [17]. Several researchers have suggested improvements to reduce these perturbations. Loudjani [24] proposed to use thermal (IR) channels 4 and 5 of the AVHRR to quantify for a given pixel, the decrease of apparent temperature and its coupling with increased reflectance in the visible band. This phenomenon indicates the presence of sub-pixel clouds, not detectable with the Maximum Value Composite [17]. After identification of the dates, a sliding window adapted to the perturbation of the pixel can be computed. This allows us to optimise a filtering interval, adapted in the BISE (Best Index Slope Extraction) method as described by Viouy [25]. We adhered this procedure to filter the GVI data on a weekly basis. This allowed us to produce smoothed profiles of the Normalised Difference Vegetation Index which document the phenological characteristics of the different African biomes.

3.2 Classification and NDVI temporal behaviour

3.2.1 NDVI temporal behaviour

The NDVI temporal behaviour of African biomes allows us to characterise the reflective behaviour of vegetation [15] or more precisely biome phenology. Annual cycles are characterised by

an average yearly NDVI level related to photosynthetic active radiation absorption (APAR). Biome and hence, seasonal NDVI variations, often show a plateau, characteristic for the biome type. The full yearly NDVI profiles can be parametrised with different variables, which actually describe biome phenology. Hence it is possible to identify: (i) the dates on which a significant difference between the NDVI of a certain biome and that of bare soil can be observed, (ii) the slope of the NDVI increase in function of time, which is related to the increase of Net Primary Productivity (NPP) for a certain biome, (iii) the length of the NDVI plateau, providing us a measure of the extent of the growth period for a certain biome, (iv) the height of the NDVI plateau, indicating the efficiency of a certain biome for the absorption of PAR, (v) the dates on which a certain biome elicits senescence and abscission of its green cover, and hence ends its yearly assimilation cycle.

3.2.2 Standard colour categories

Colour hue is made dependent on the NDVI levels of the signal in the chromatic range composed of red, yellow, green, blue and purple. Red indicates a low vegetation density (sparse vegetation) and purple a high vegetation density. Colour saturation is made dependent on the length of the NDVI maximal level. The longer the NDVI stays on its plateau level, of the higher a certain colour is saturated and this for each range of colour hue. We can demonstrate that color saturation levels allow us to differentiate the intervals between the NDVI maximal plateau's, which are linked with the rainy season patterns observed respectively North and South of the equator.

3.2.3 The Automatic Classification of Time Series (ACTS)

The map shown in figure 2 is the result of an unsupervised classification of a five years period (1986-1990) of NOAA/AVHRR-GVI data, acquired and processed according to the approach of Viouy [26]. Viouy's classification method (ACTS) is based on the principle of clustering pixels behaviour in function of time. It allows to associate pixel behaviour in several categories. Concerning its application for the African continent, we put forward twenty five categories. This number of categories is more adapted to a confrontation with cartographic data already published for this continent [14]. A colour look-up table (LUT) gives us more information on the length of the growth phase as well as on the NDVI levels. In red, green and purple, biomes eliciting a relatively short growth period and

respectively low, medium and high NDVI levels can be distinguished. Biomes with a high NDVI level and a long growing phase are associated with the colour blue. This cartographic representation enables us to highlight various types of NDVI behaviour observed and to associate known biomes with NDVI behavioural types.

4. Results and discussion

4.1 Description of NDVI temporal behaviour in relation to main African biomes

A cartographic synthesis based on a dedicated colour table, allows us to better interpretate and understand NDVI temporal behaviour.

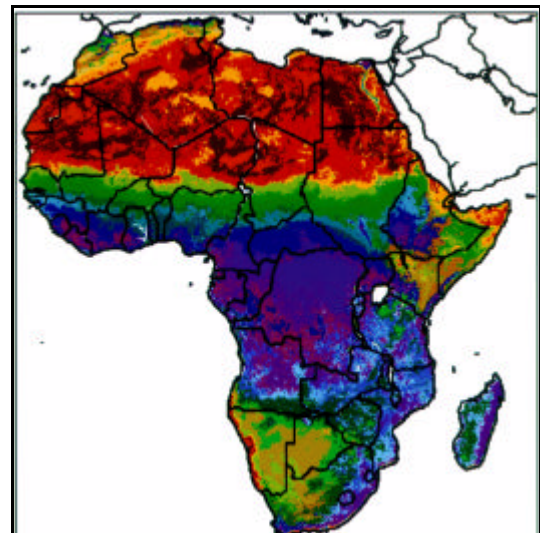


Figure 2 : Result of an unsupervised classification (ACTS) of a five year GVI data set for Africa (1986-1990, with omission of 1988). Colour codes are as follows: Red : low vegetation density ; Purple: high vegetation density. Colour saturation depends on the length of the NDVI plateau, colour tone depends on the maximal NDVI level.

In figure 2 it can clearly observe a category corresponding with desert featuring red as predominant colour. It includes subcategories of orangey yellow and pink. The general shape of desert related NDVI temporal profiles does not change, unlike the locations of the four desert classes associated colour table which corresponding with the maximal NDVI level over a year. We can observe that the colour table allows us to discriminate and geo-localise sandy from stony desertic zones. This is a known NDVI property since it is dependent on the optical characteristics of bare soil e.g. as well as its

surface roughness [27]. Directly North and South bound of the Saharian desert, pale green identifies the emergence of the vegetated biomes. These biomes are characterized by the NDVI featuring low levels and a short growth phase. This behaviour is typical for desertic transition zones where vegetation is very sparse eliciting a short growth period. Most frequently, this NDVI behaviour corresponds with Sahelian steppe biomes experiencing a very short rainy season. Sahelian vegetation has a fractional cover which is generally sparse and quite variable. Consequently, as far as the variability of the NDVI is concerned, we have to take into account soil optical behaviour since it does significantly influence the NDVI of the target pixels. The Sahel zones are consistently localised on the borders of the Sahara, the Kalahari and Eastern African deserts. On the outer borders of these zones, one can observe a predominantly green colour category for the two hemispheres. This category is related to a short growth period and a medium maximal NDVI level. This colour category corresponds with savanna where arboreous, bushy and herbaceous vegetation is present in variable proportions and well developed. Phenology, specifically for the herbaceous stratum, is strongly dependent on the abundance of precipitation. This in part, explains the briefness of the growing period. Zones delimited by the green colour category typically correspond with Sudanese and Zambian savannas. The differences in latitude interval between the Northern and Southern hemispheres referenced to the equator stems from the difference in respective rainfall regimes. This difference is emphasised by different colortone of green. The blue colour category can be divided into two areas. A zone coded in deep-blue in the Northern hemisphere and a zone coded in grey-blue in the Southern hemisphere. The blue colour category has a longer growing phase than the categories already mentioned above. It is related with Guinean savannas and dry tropical forests. Typically the length of the growing phase is extended and relates to longer and more intense rainy seasons. As indicated by the previous colour category, the temporal position of the growth phase is different North and South of the equator. The relatively high NDVI level can be accounted for by the presence of a quite dense arboreous cover allowing for a longer growing season. Finally, tropical forest biomes are coded in the colour purple. It includes three subcategories, each of which has a high NDVI level, but whose growing phases have different intervals. This suggests the possibility of discriminating between evergreen and semi-deciduous forests, or non-seasonal versus seasonal tropical forest biomes.

4.2 Multitemporal behaviour of different savanna biomes

Since savanna is prominently experiencing anthropogenic as well as climate influences, it is quite meaningful to corroborate our methodology in more detail with this spatially heterogeneous and highly stratified African biome.

4.2.1 Documentation

To validate our cartographic representation at a GVI scale, we used data collected on five sites used as field control points, with a 30 x 30 km dimension along the central North-South transect of the SALT project. We have chosen this transect so that it crosses a group of formations of savanna eliciting a large variability related to respective proportions of woody, shrubby and herbaceous vegetation. This variability originates from a structure characterised by parallel longitudinal strips perpendicular to a North-South oriented precipitation gradient. Moving up from South to North along this transect, very quickly transitions appear between the different savanna types. Informations acquired in the field, contributed to the development of a surface occupation map for each of the five field study sites. From South to North, corresponding document (mainly from SPOT imagery) has been collected by different authors [28,7,29,30,31]. Through these maps were established to characterise the state of the surface, they are documented by captions which elicit differences according to the authors who classified the imagery. This is quite illustrative for the differences approach to describe surfaces heterogeneity. Depending on the SALT site selected, we dispose of cartographic information related to soil granulometry and colour, structural information on vegetation formations in terms of cover stratification and a typology of natural savanna formations. This information confirms that each author's study is specific for a characteristic type of savanna. Moreover, the entire set of formations described for these study sites is representative for the different savannas types known to be present in Western Africa. We localised the five sites on AVHRR imagery so as to track the temporal evolution of their NDVI behaviour at the pixel level. Hence, we could observe that each of the five sites belongs to a particular clusterclass gets more detailed than the coverytype from Schnell's classification. For the five SALT field study sites, we could associate growth cycle attributes with the five

cluster classes. Each of the savanna cluster classes was then documented in terms of canopy structure and the phenology.

4.2.2 Savanna comparative phenology

The yearly evolution of the NDVI for the five savanna categories are illustrated on the caption on figure 3. From South to North, we can observe a reduction in length of the growing period, a shift of the growing period of the latter towards June-July, as well as a gradual reduction of the maximal level NDVI. We can clearly demonstrate the effect of the precipitation amount on the length and the take-off date of the growing period [32].

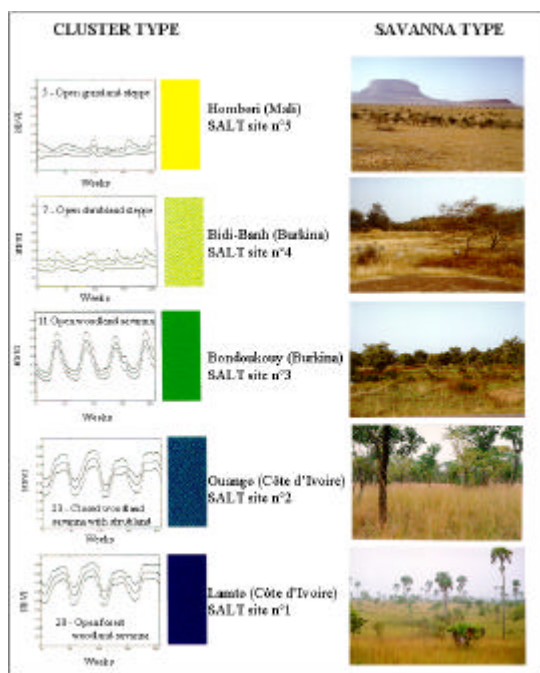


Figure 3 : Comparison of five savanna types at the level of NDVI behaviour and cover structure.

The latter phenomenon is related to a gradual delay of the onset of chlorophyll build-up. For environments characterised by a high spatial heterogeneity, it has been shown that the NDVI is sensitive to vegetation cover fraction and to leaf area index variations, especially when the latter has values lower than 3. It is suggested, that NDVI temporal evolution can be associated with a gradual decrease of the ligneous fraction compared with the underlying herbaceous stratum for the five categories. The NDVI temporal evolution of closed woodland (classes 20 and 23) is marked by a plateau-shaped NDVI temporal profile, highlighting the length of the growing season, whereas the evolution of the open woodland is characterised by NDVI peak which indicates a much shorter growing period. Its height is associated with cover structure

(vertical stratification and fractional cover). Closed woodland has an important ligneous component as well as a continuous herbaceous stratum entailing a lasting and high NDVI level. Open woodland is composed of a loose and sparse ligneous cover, a spatially discontinuous herbaceous stratum and a significant proportion of bare soil. In this case, annual NDVI behaviour translates a strong interaction between precipitation input and vegetation response. The NDVI response at the end of the growing cycle of this cover type is marked by a quick drop of the NDVI level indicating a strong dependence on the hydrological regime. In general, the annual NDVI behaviour of these savanna types is consistent with the generic scheme commonly adopted for this type of formations. Moreover a pluri-annual approach enables us to detect NDVI behavioural differences for a given savanna types.

4.2.3 Dynamics of savanna formations

A closer study of the map based on clustering of multitemporal AVHRR data enables us to individualise transition categories generally showing an alveolar shape. The spatial variability of the extent of these categories being directly affected by climatic and antropogenic factors, accounts for the savanna biome response to these external influences. One can mention the Northern Sudanese transition area, the Kalahari border areas, or the former dry forests in Austral Africa, which are now cleared. As far as savannas are concerned, we can describe and follow the evolution of the herbaceous stratum between 1986 and 1990 in the open shrubland steppe (Northern sudanese zone). We illustrate the evolution of the NDVI during this time interval in figure 4.

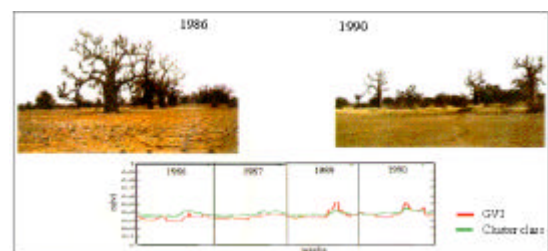


Figure 4 : Multitemporal NDVI evolution of a savanna in Bidi-Bahn area (Ouahigouya district, Burkina-Faso ; 13° North- 2° West, alt. 329 m). Total rainfall are: 1986 (590 mm) ; 1987 (457 mm) ; 1988 (708 mm, not presented in the graph); 1989 (698 mm) ; 1990 (404 mm), source: Ministère de l'Eau/DEP/Projet Bilan d'Eau; BEWACO, 1991.

With a continuous line, the NDVI behaviour of the SALT site number 4 occupied by savanna is plotted. The red line represents the average behaviour of seven pixels with which this site corresponds. Observe that the annual cycles are quite monotonous in 1986 and 1987, whereas in 1989 and 1990, a peak of the NDVI appears in the middle of the growing season. This feature can be associated with a modification of the vegetal cover from field observations made during ground surveys. We could observe the development of a herbaceous stratum on this site during the observation period, a stratum being almost absent in 1986. The most commonly adopted interpretation is the quasi-destruction in this area of the herbaceous stratum during the big drought of the eighties and the refill of the hydrological reserves from 1986 onwards. Remote sensing observations allowed us to follow the response of this herbaceous stratum towards the availability of the soil water reserves with a latent period of one or two years, depending on the 1988 NDVI behaviour. Data from 1988 were not processed, due to platform orbital drifting.

4.3 Originality compared with classical cartography and limitations of the approach

With a cartographic synthesis of NDVI behaviour, it appears that the major entities of the biogeographical zones of the African continent are both identifiable and consistent with Schnell's works and Fontès [33]. For a few zones though, discrepancies with classical cartography do exist. These differences may originate from two types of factors intrinsically related to the type of sensor used.

4.3.1 Type of information presented

A cartographic representation of the annual and inter-annual variations of the NDVI, allow us to obtain a geo-coded product related to the dynamics of the main African biomes. This behavioural synthesis applies to vegetation effectively observed, and not to temporally static translations of the average behaviour of African natural biomes. We developed a typology of NDVI behaviour directly related to biome types, which one a result of anthropogenic pressure (agriculture, fires) and climatic conditions prevailing during a more or less recent period. Basically, a given biome (cluster type) is attributed a dominant colour characterising its average NDVI temporal evolution, as well as a variation in colour depth corresponding with a translation of its response as influenced by exogenous constraints. Note that even with quite large a spatial scale of observations (GVI), this representation does retain certain levels of cover

type heterogeneity, such as patches corresponding with intense deforestation activity, observable South of the Congolese massif. Furthermore, our clustering method actually elicits the delimitation of vegetal formations in barely described regions, such as the forests on the Ethiopian high plateau or the Moxico state forests in Angola. It also allows to detect human influences related to agricultural activity. The latter can be seen in the Western part of Malagasy, as well as in Congo Democratic Republic where intra-forest agricultural activity can be identified.

4.3.2 Limitations of the approach

The limitations of the approach previously outlined, are closely linked with the choice of pixel spatial resolution as well as with the processing methodology applied. GVI data have been processed on the basis of a filtering algorithm based on the Maximum Value Composite [17]. It is well known that the MVC approach favours the selection of specific observation conditions. The choice of the type of vegetation index is also a very important one, since especially the NDVI, is sensitive to bare soil and to atmospheric perturbations. Some studies are currently in progress on the definition and use of new indices more specifically dedicated to the monitoring of responses of vegetation [34]. To correct for atmospheric perturbations, surface reflectances have been computed with the SMAC code for climatologies. These corrected reflectances have been used to compute the NDVI at the continental surface level. It has been demonstrated [35] that these corrections, performed at this scale, being significant improvements compared to data not corrected for atmospheric perturbations. Most of the atmospheric perturbations related to optical remote sensing are due to effects provoked by atmospheric aerosols and water vapour content.

5. Conclusions

We have designed a cartographic method, in which a synthesis of the temporal behaviour of the major African biomes has been achieved on the basis of a GVI data set acquired with the NOAA-AVHRR instrument. The classification algorithm (ACTS) used is well adapted to the data set which has been used since the latter is geo-encoded, and acquired with a regular weekly interval compatible with the objective of detailed phenological tracking. Our study relies on measurements of a vegetation index (the NDVI) where atmospheric perturbations have been

corrected for. It is nonetheless clear that we are explicitly dependent in our interpretations, on the empirism related to linking of NDVI with surface biophysical state variables determining the remote sensing signal. This empirism is a major limitation in terms of our understanding and physical modelling of phenomena involved in processes at the interface of the surface and the atmosphere. The identification of these limitations is an essential task and their understanding constitutes a challenge for research to come in the following years. The interest of the method proposed, lies in the analysis and cartographic synthesis of the dynamics of vegetational populations or biomes. It offers an original approach for the arduous problem of representing temporal NDVI evolutions on a cartographic basis. We may state that this representation is consistent with currently accepted biome representations, as far as the main African biomes are concerned. Moreover, our approach allows information on biome types to be more easily interpreted by tracking NDVI behaviour over long period of time and this, for every pixel within its cluster class. In this respect our methodology radically distinguishes itself from classical cartographic methods and represents a valuable tool for biogeographic studies on large scale and over large periods of time. The empirical aspect constitutes a stumbling stone for in depth interpretations. Nevertheless, our method upholds a certain number of assets. We can particularly quote its potential for permanent actualisation, GVI data being acquired and distributed permanently on an operational basis over the globe. In view of the new

earth observing space missions planned (VEGETATION, POLDER, ...), asset may prove to be even more promising. Hence, this strategy benefits from the features of remote sensing technology, to mention repetitiveness and easy observation over large areas. These advantages offer high flexibility when selecting temporal and spatial windows, for the latter can easily be adapted to the objectives of new studies undertaken. Finally may we underline the interest in relying on standardised procedures for acquisition and processing, reducing the risks of heterogeneity in cluster nomenclature. Applied to biomes which are very sensitive to climatic and anthropogenic effects, e.g. savannas, our approach at GVI scale gives account of the behaviour of this heterogeneous and spatially strongly stratified environment. Validations based on maps and ground surveys proves that we can characterise different types of savanna spatio-temporally. Finally, note that to describe these phenomena on a continental scale by using classical maps, even with elaborate ground based observations, this characterization would have been quite difficult.

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